Water Quality and Beaver Created Ecosystems

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PIE Rivers 2025 Annual Meeting

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Plum Island Ecosystems Long Term Ecological Research

NSF

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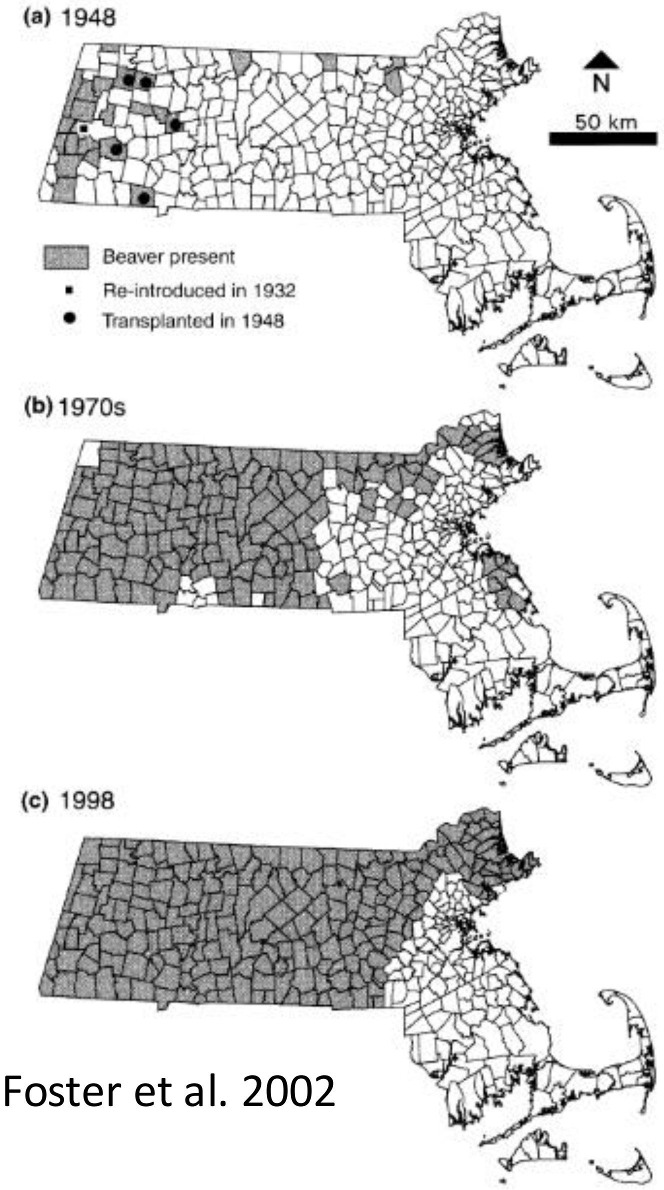
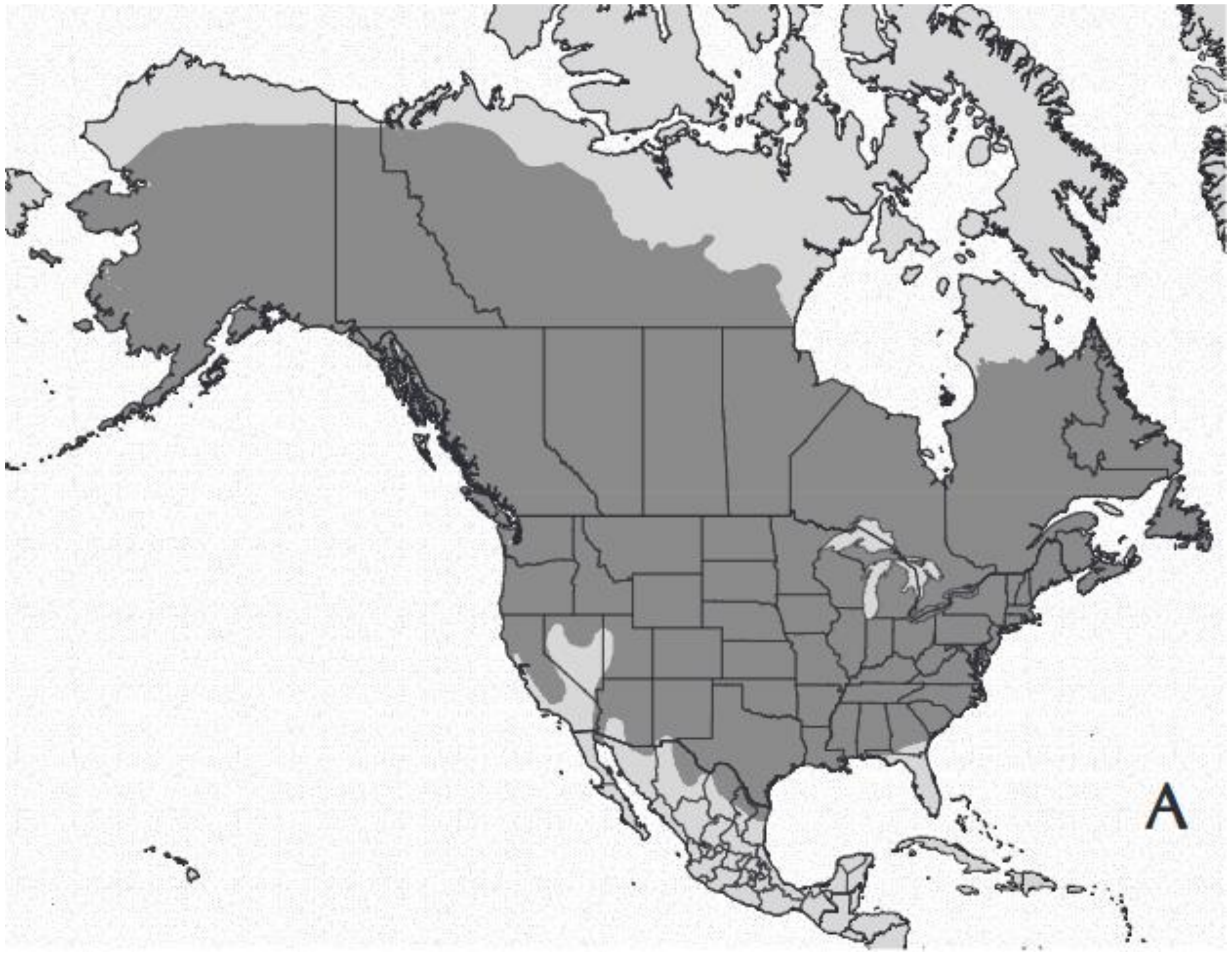
Beaver populations are making a comeback



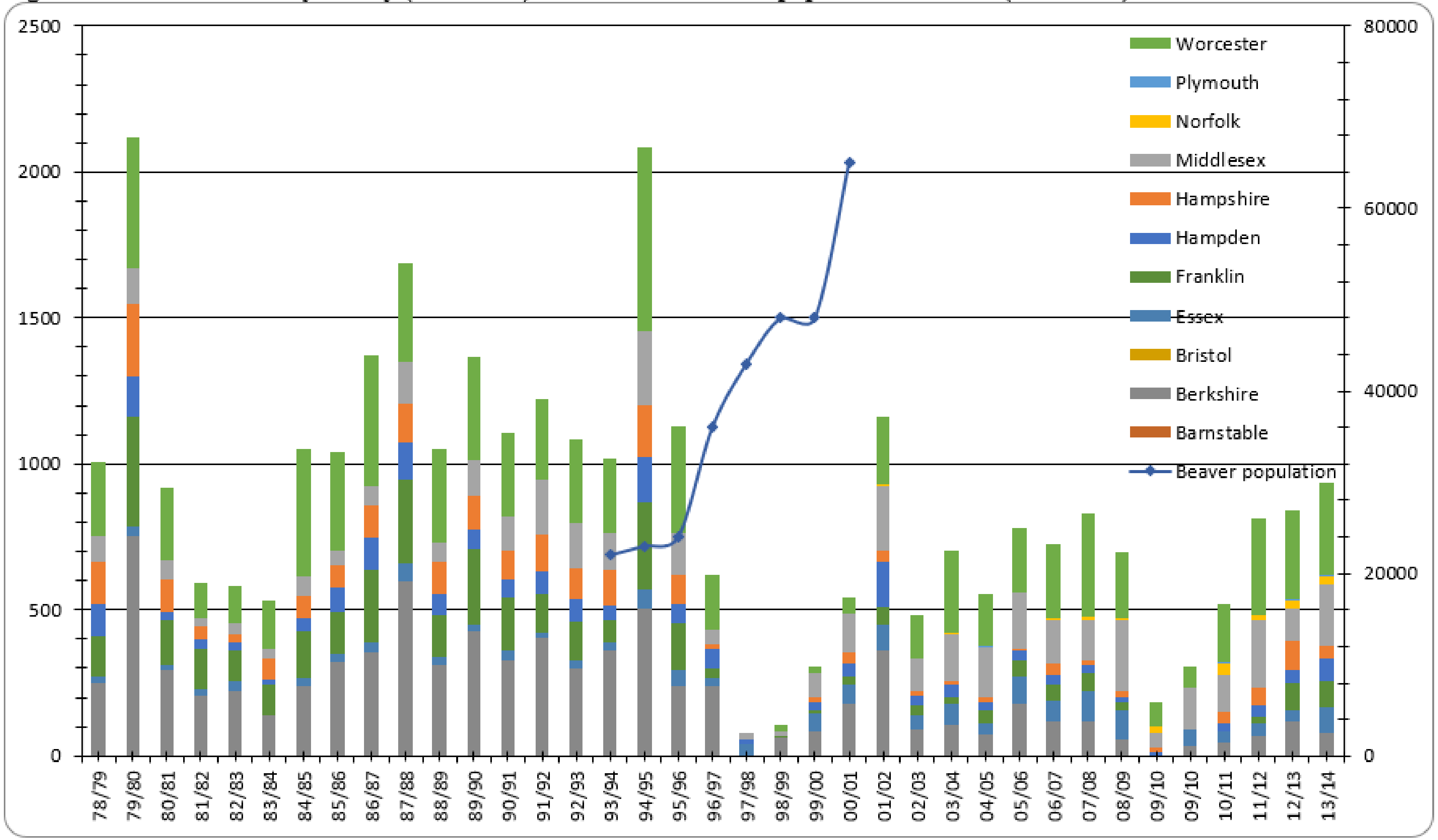
Foster et al. 2002



Pollock et al. 2003

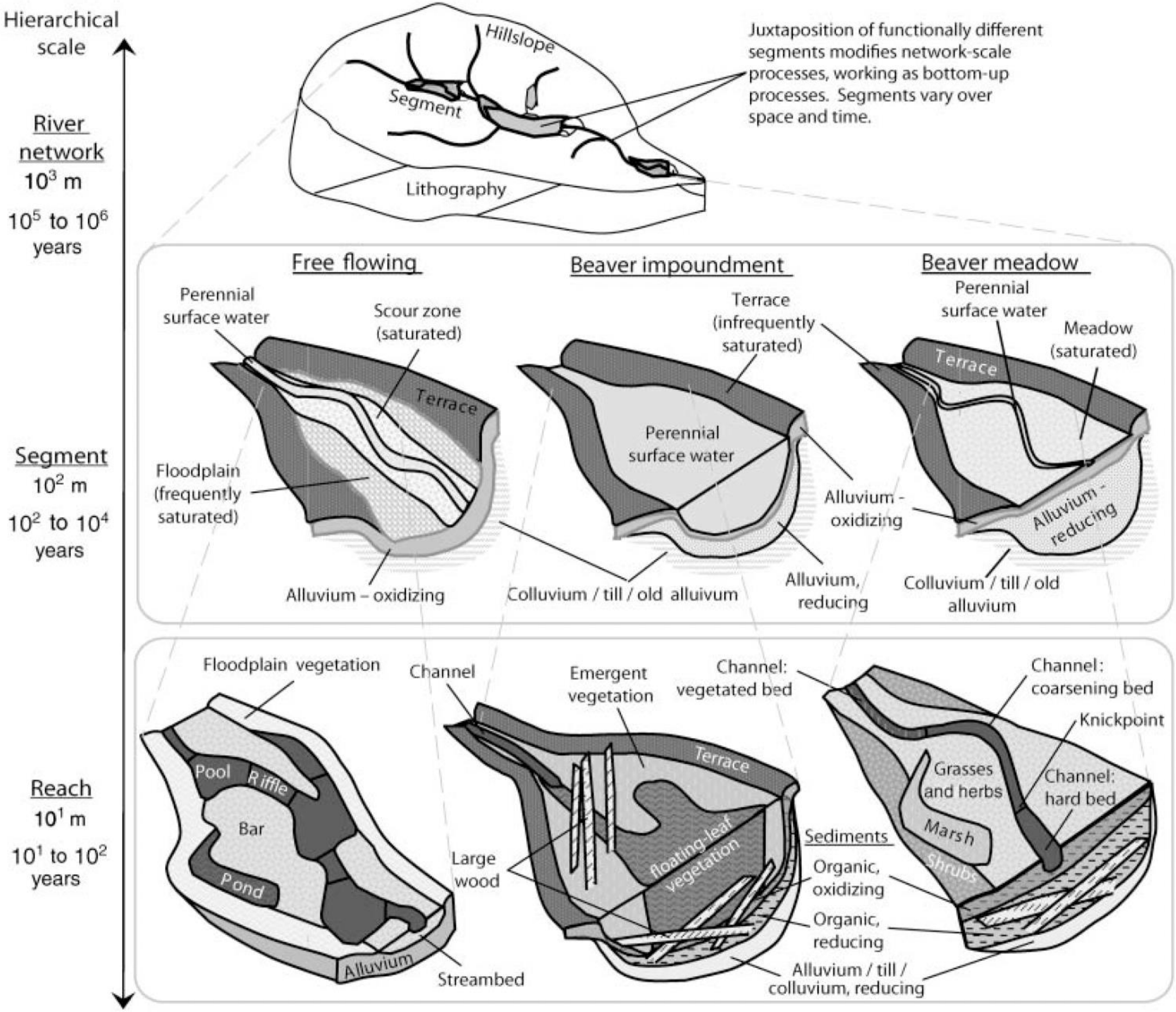
No one really knows how many beaver are currently in MA!

Figure 1. Beaver harvest by county (1978-2014) and statewide beaver population estimate (1994-2001)



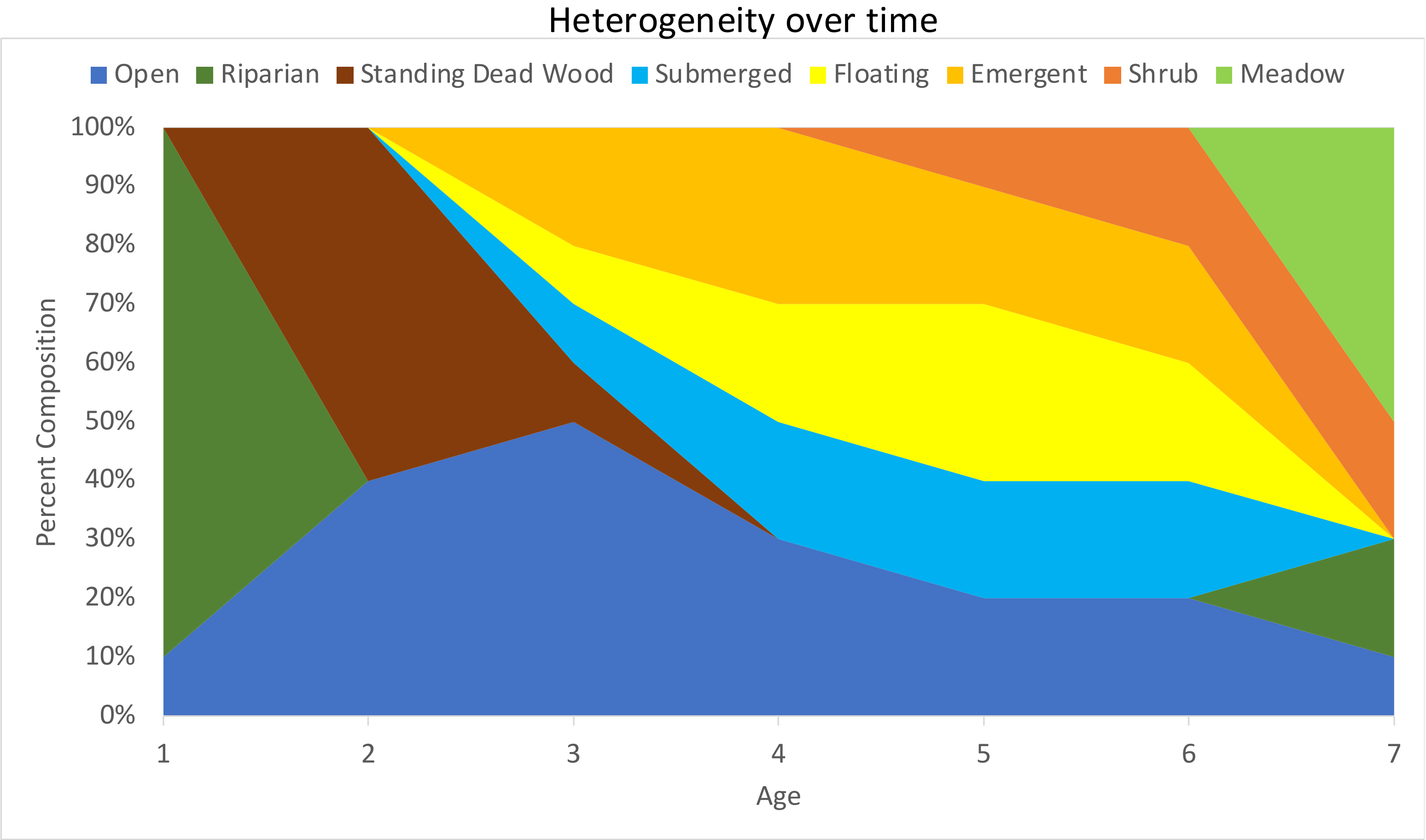
Beaver are ecosystem engineers

Beaver Discontinuum



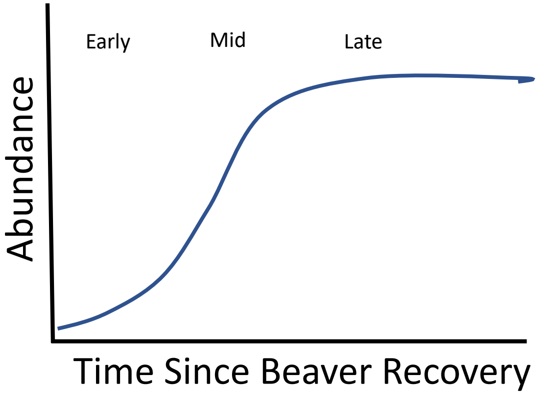
Burchsted et al. 2010

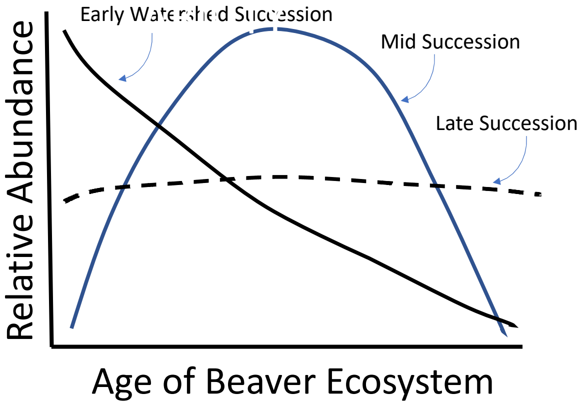
Beaver Created Ecosystems undergo succession



Open water
To
Submerged/Floating
To
Emergent
To
Shrub/Meadow (abandonment)

Characterize Abundance and Age Distribution in Entire Watersheds

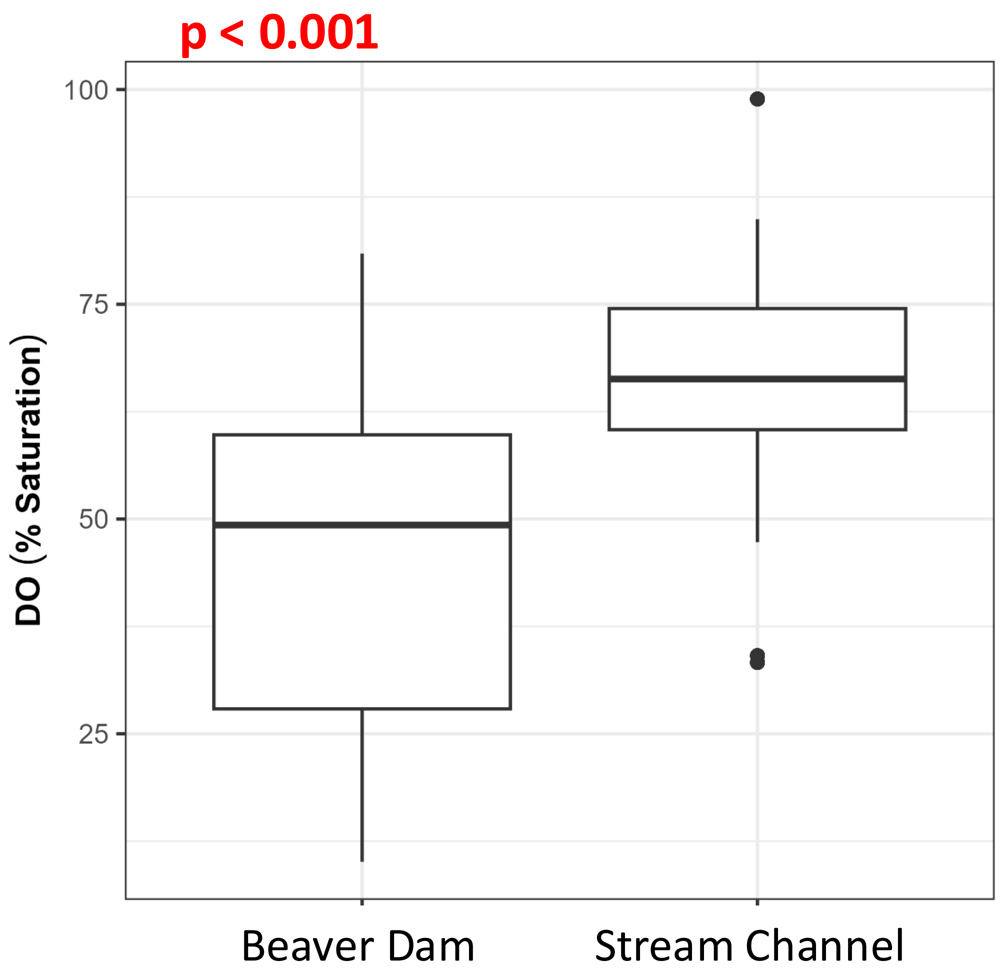




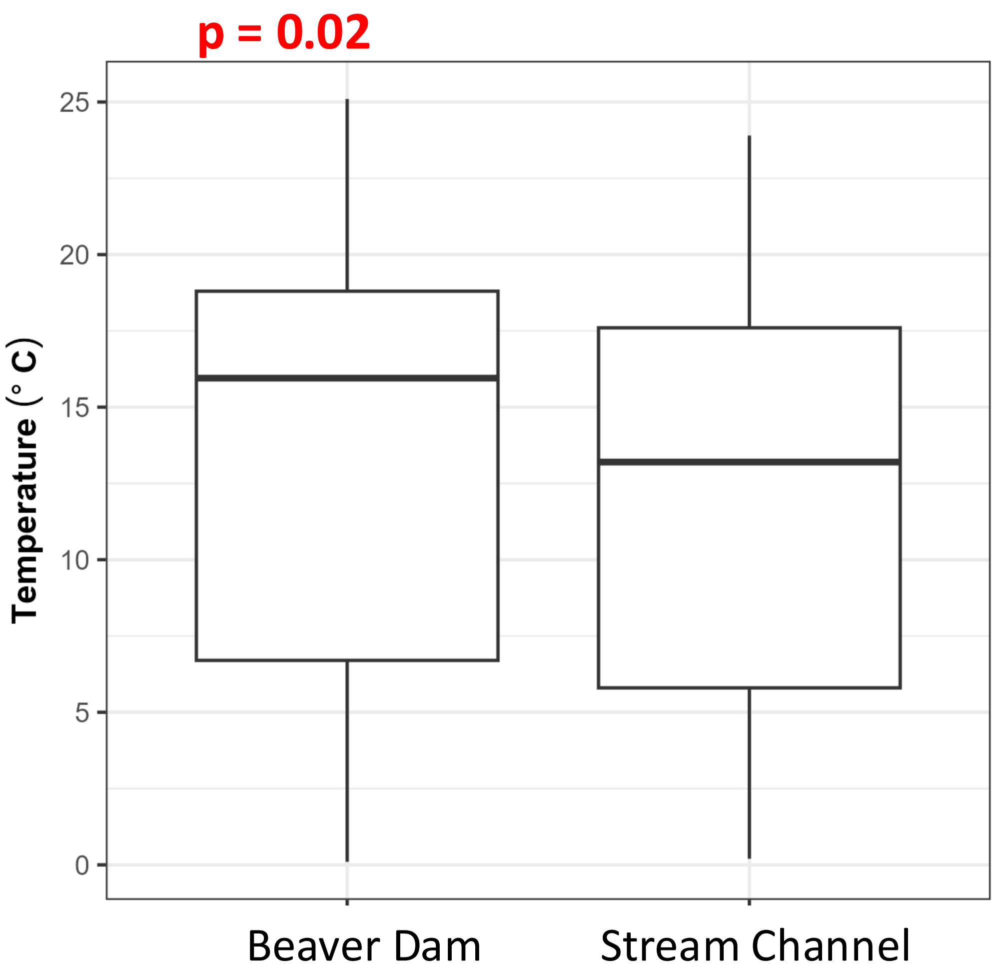
From Pending Proposal: Helton, Wollheim, Holgerson

Intensively-studied beaver pond on Cart Creek, Newbury, MA, July 2019. Photo by Chris Whitney

What are the Water Quality Implications?

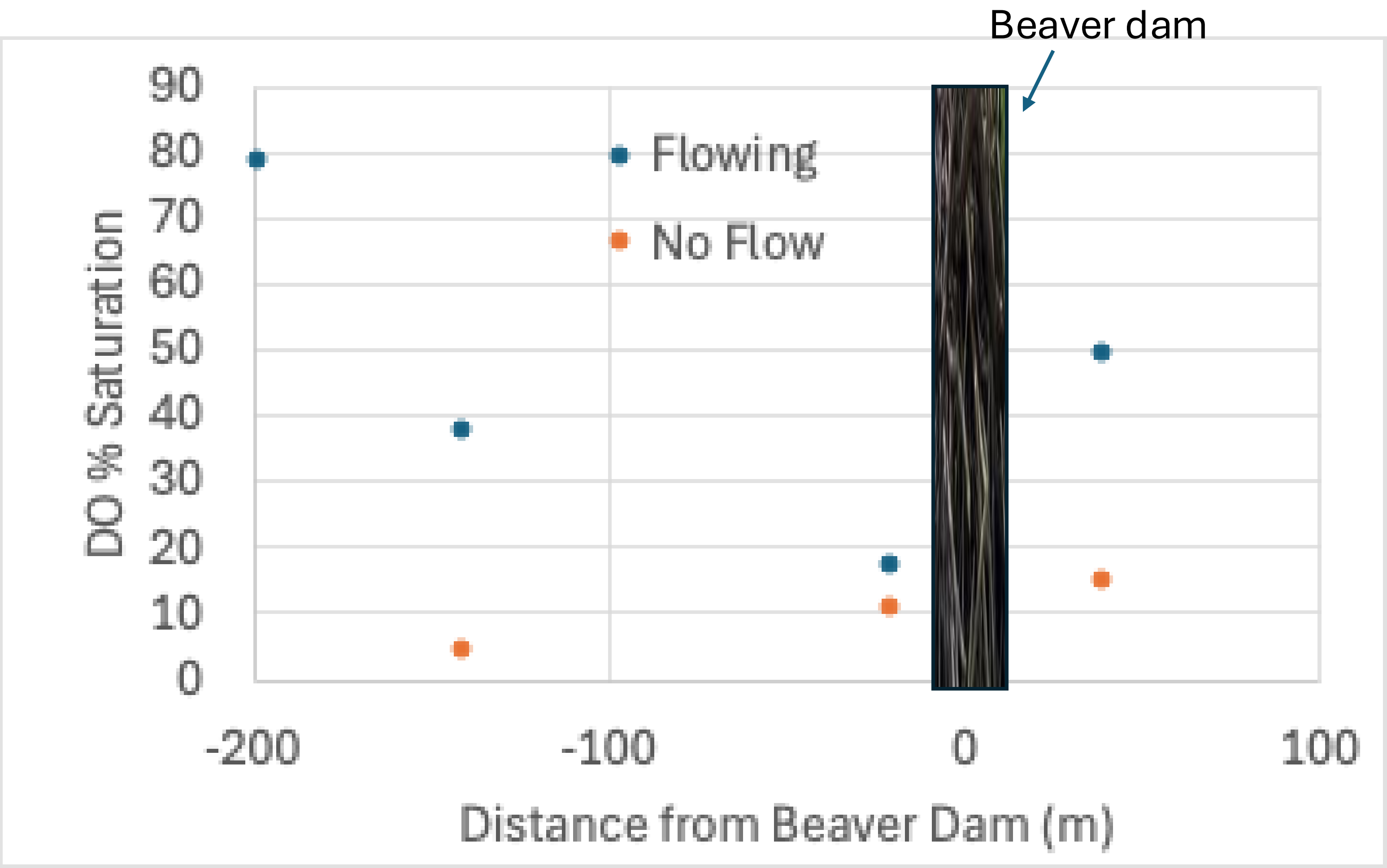


Lower DO

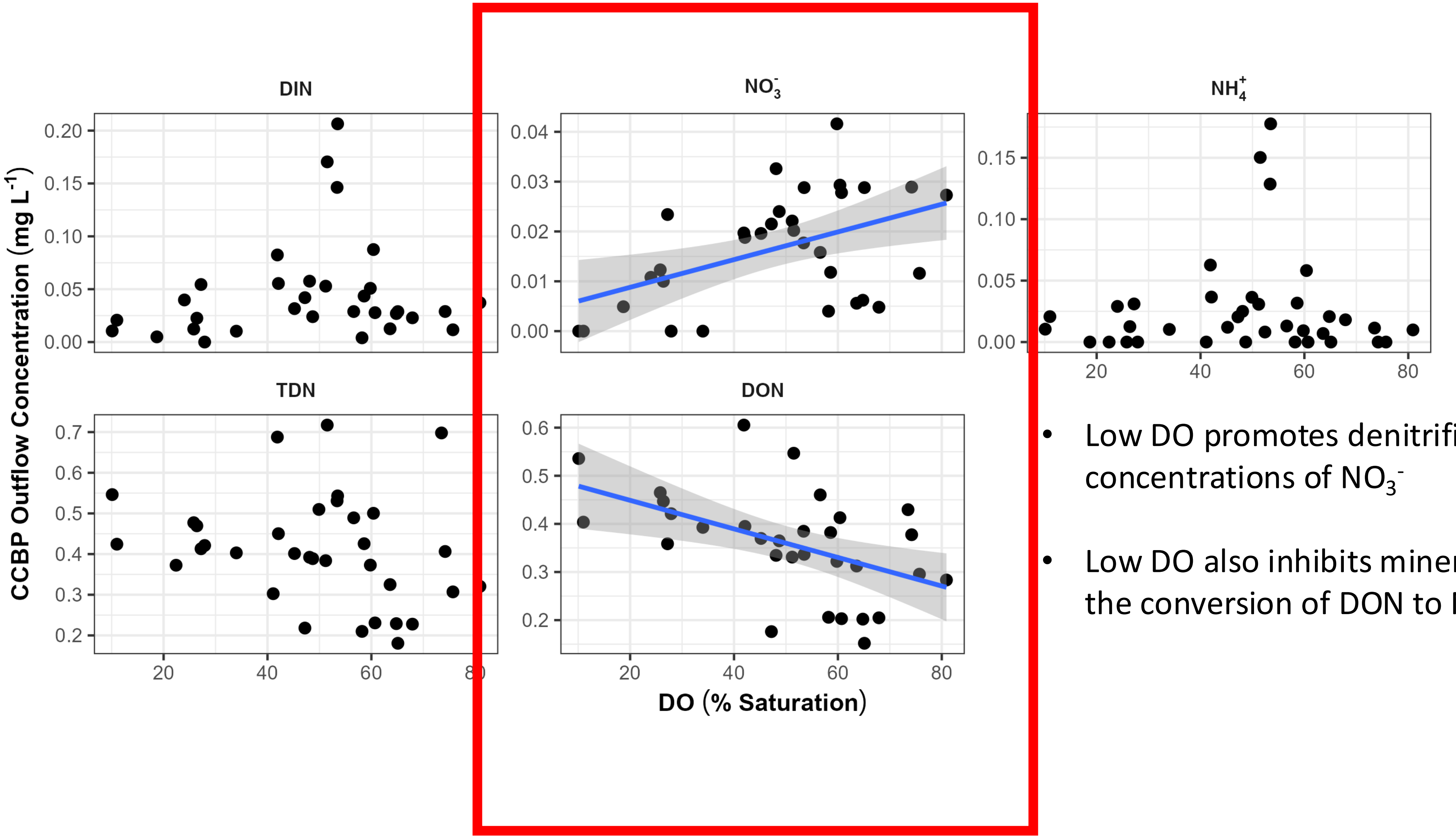


Warmer Temperatures (summer)

We can see this as water moves through a BCE

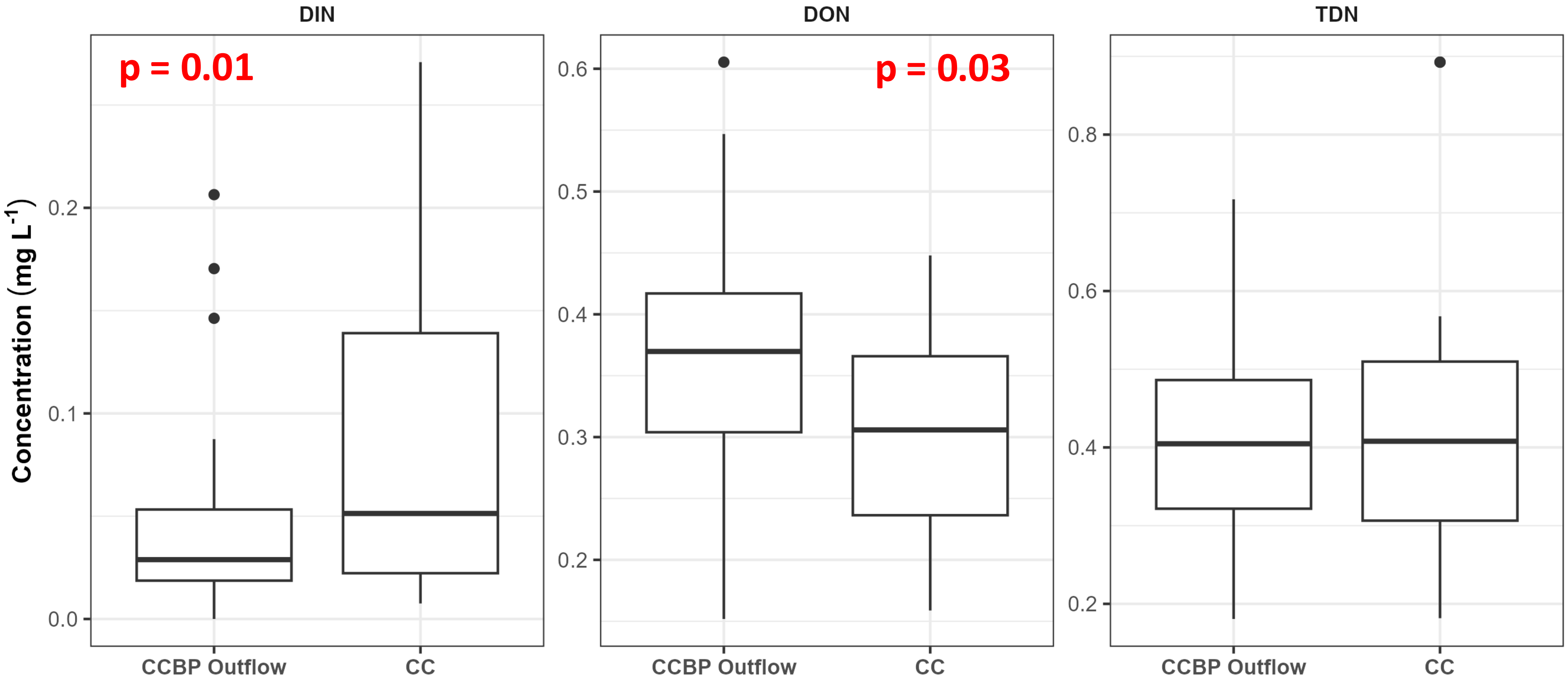


Decline in DO affects nitrogen

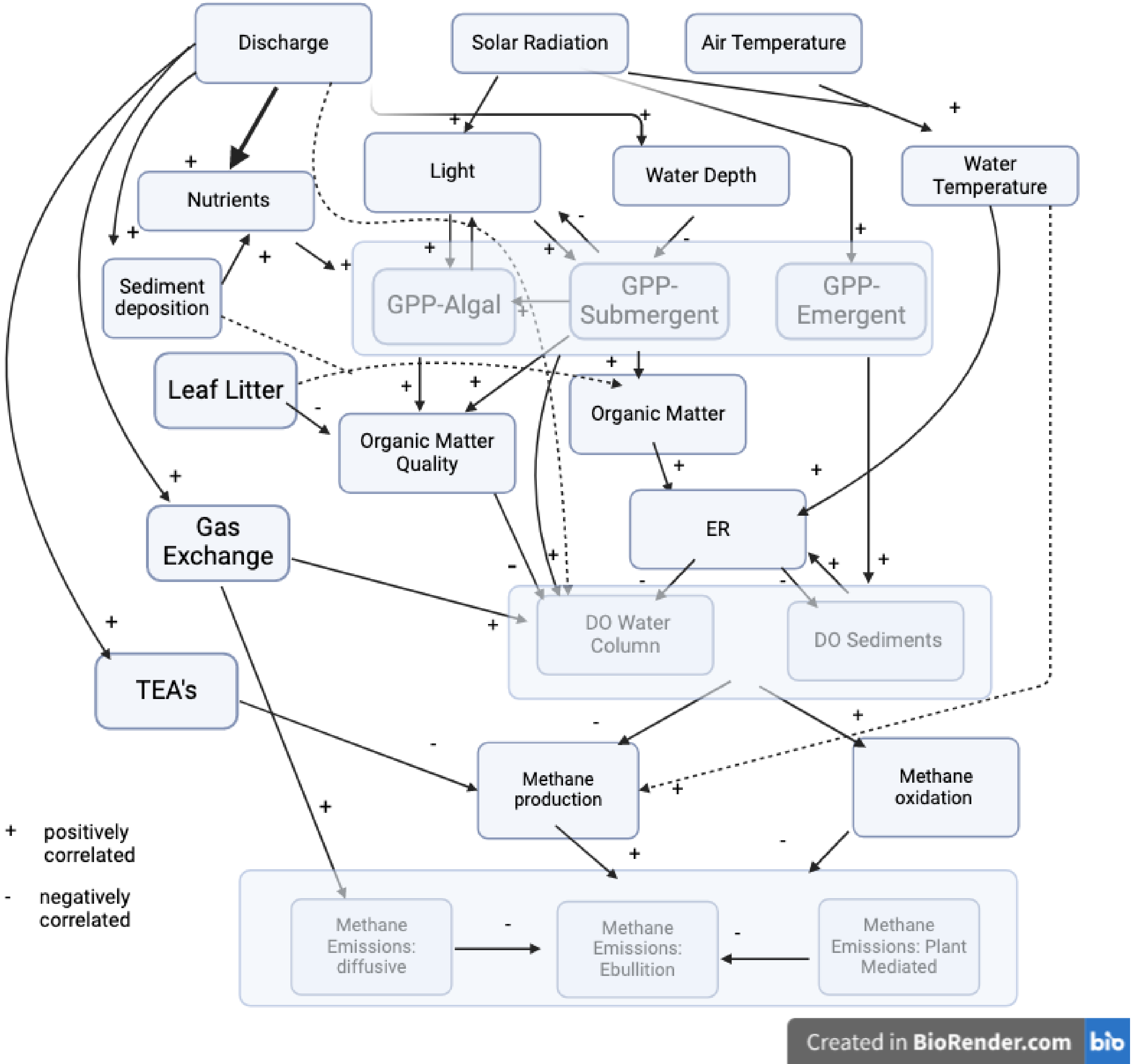


- Low DO promotes denitrification, driving down concentrations of NO_3^-
- Low DO also inhibits mineralization, preventing the conversion of DON to NH_4^+

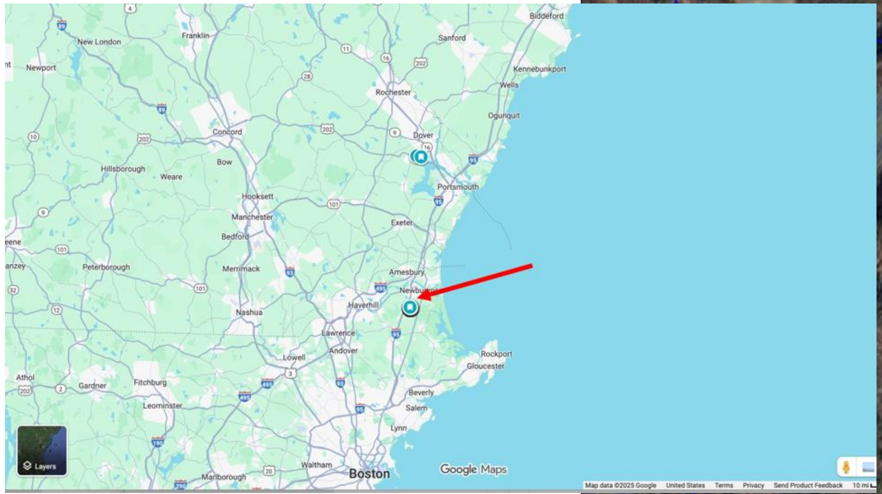
Beaver pond has lower DIN and higher DON than channel



Algal bloom in the intensively-studied beaver pond on Cart Creek, Newbury, MA, August 2015. Photo by Chris Whitney


Discharge
Solar Radiation
Air Temperature
Light
Water Depth
Water Temperature
Nutrients
Sediment deposition
GPP-Algal
GPP-Submergent
GPP-Emergent
Leaf Litter
Organic Matter Quality
Organic Matter
ER
Gas Exchange
DO Water Column
DO Sediments
TEA's
Methane production
Methane oxidation
Methane Emissions: diffusive
Methane Emissions: Ebullition
Methane Emissions: Plant Mediated
+ positively correlated
- negatively correlated
Created in BioRender.com

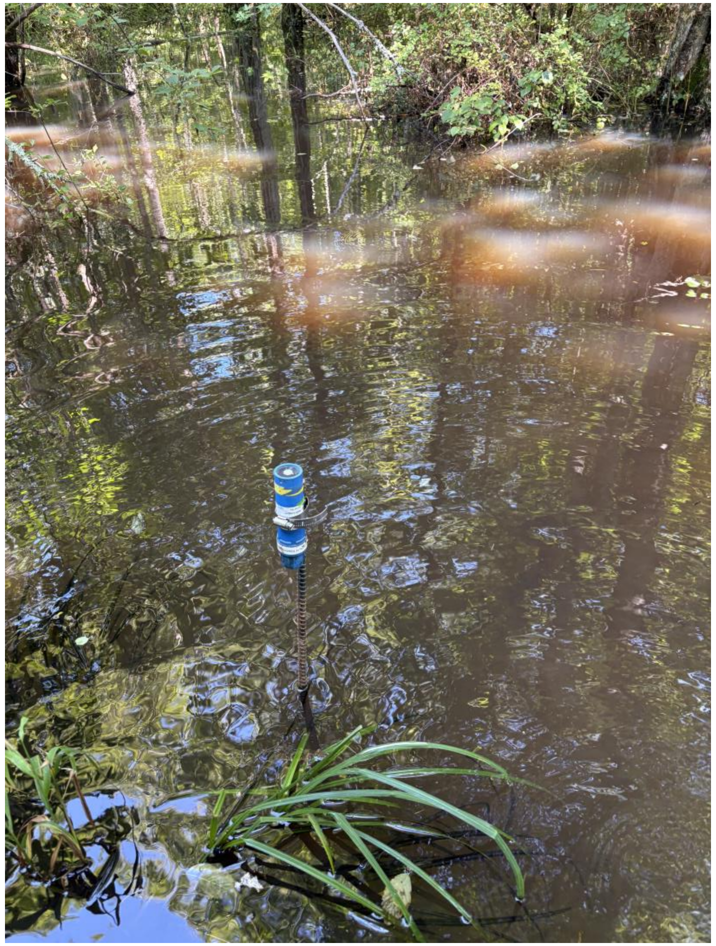
NEW Beaver Created Ecosystem (June 2025)



Martin Burns Wildlife Mgmt Area, Newbury MA.

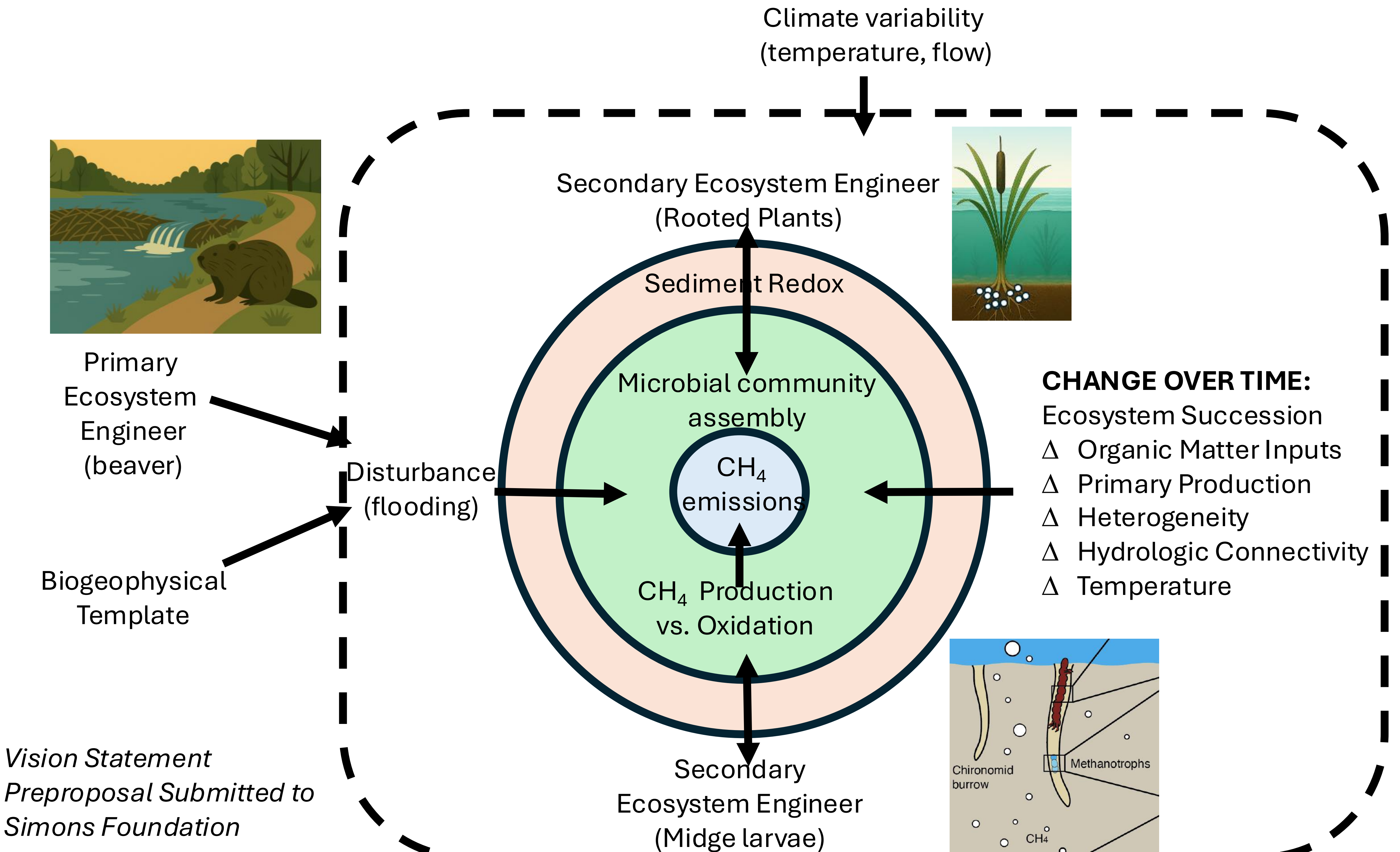
Edge of new BCE





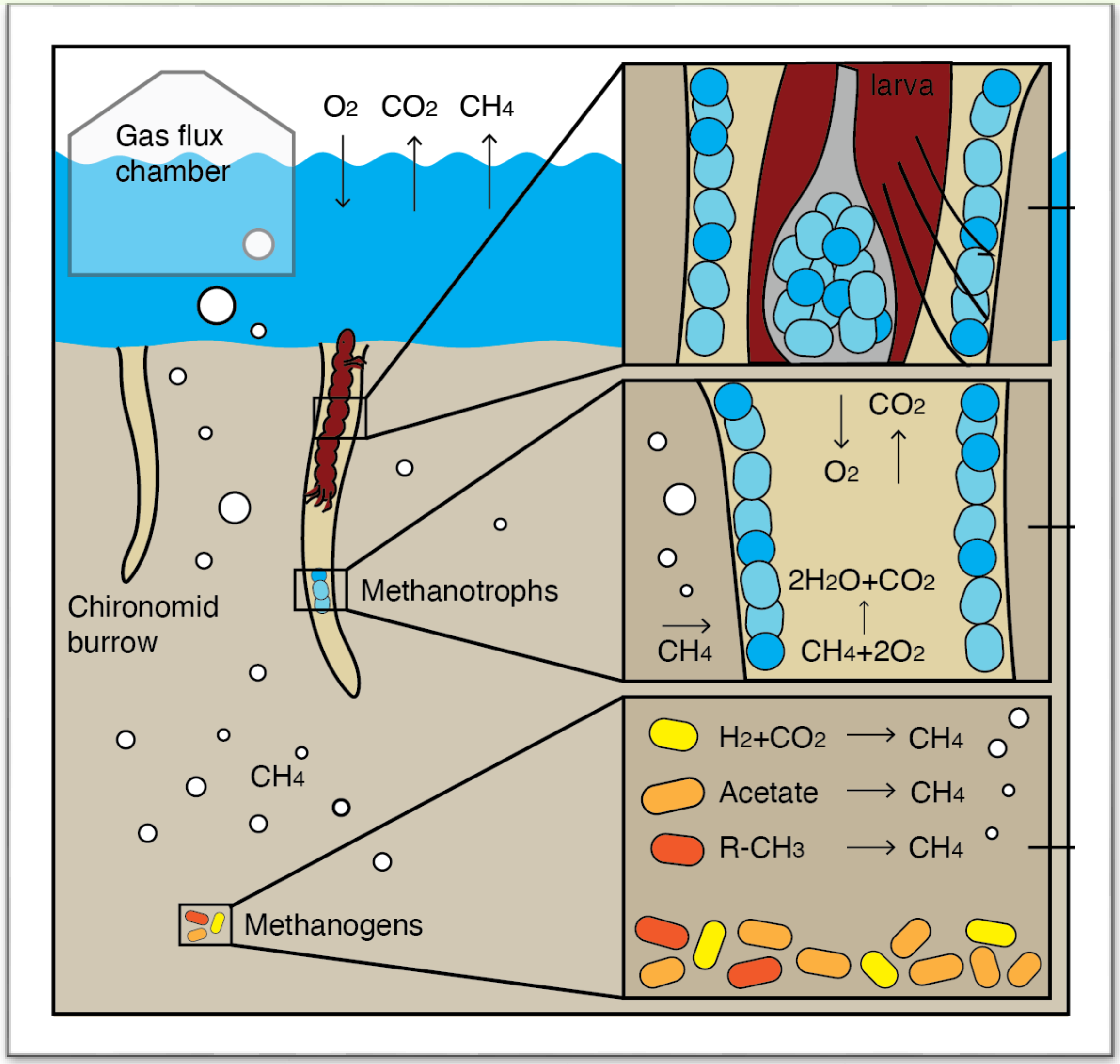




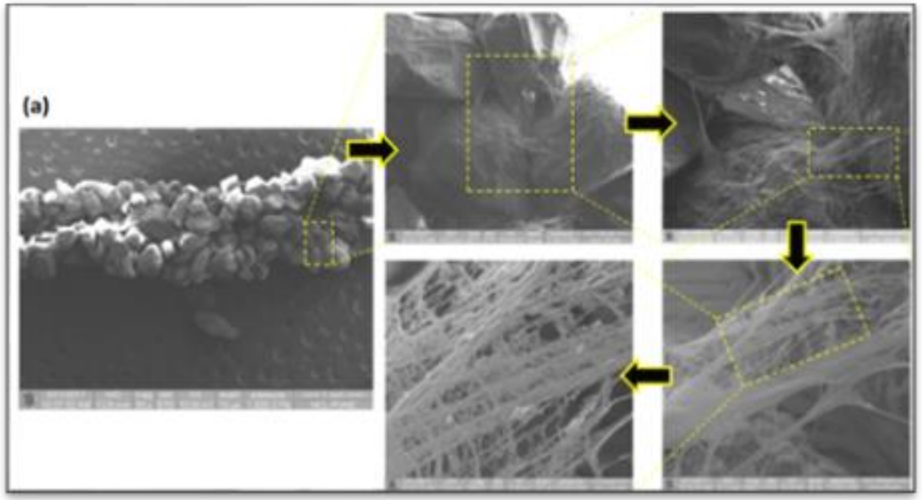
Climate variability
(temperature, flow)
Secondary Ecosystem Engineer
(Rooted Plants)
Sediment Redox
Microbial community
assembly
CH_4
emissions
CH_4 Production
vs. Oxidation
Primary
Ecosystem
Engineer
(beaver)
Disturbance
(flooding)
Biogeophysical
Template
CHANGE OVER TIME:
Ecosystem Succession
Δ Organic Matter Inputs
Δ Primary Production
Δ Heterogeneity
Δ Hydrologic Connectivity
Δ Temperature
Secondary
Ecosystem Engineer
(Midge larvae)
Chironomid
burrow
Methanotrophs
CH_4
Vision Statement
Preproposal Submitted to
Simons Foundation

Midge Larvae (Chrinomids) ”Cultivate” the sediments (ecosystems engineers part 2!)



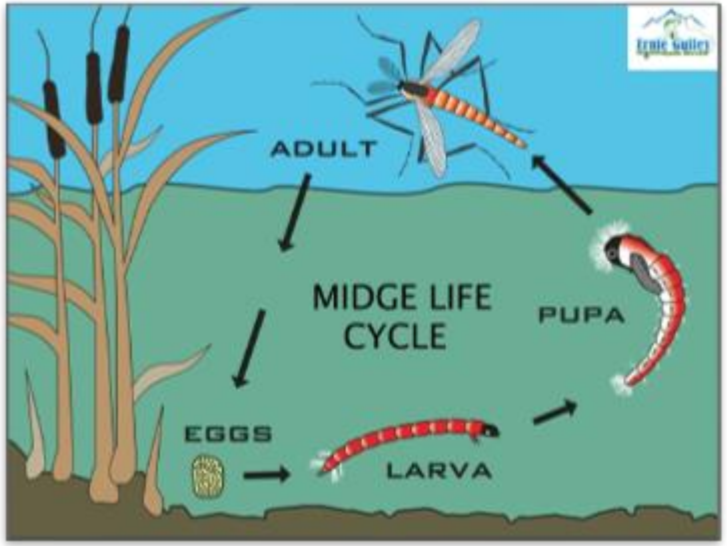
Background

SEM insoluble Chironomid silk (2020)

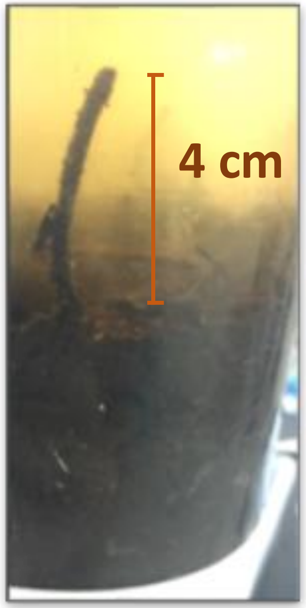


Thorat, L., Joseph, E., Nisal, A., Shukla, E., Ravikumar, A., & Nath, B. B. (2020). *Structural and physical analysis of underwater silk from housing nest composites of a tropical chironomid midge. International Journal of Biological Macromolecules.* doi:10.1016/j.ijbiomac.2020.07.07

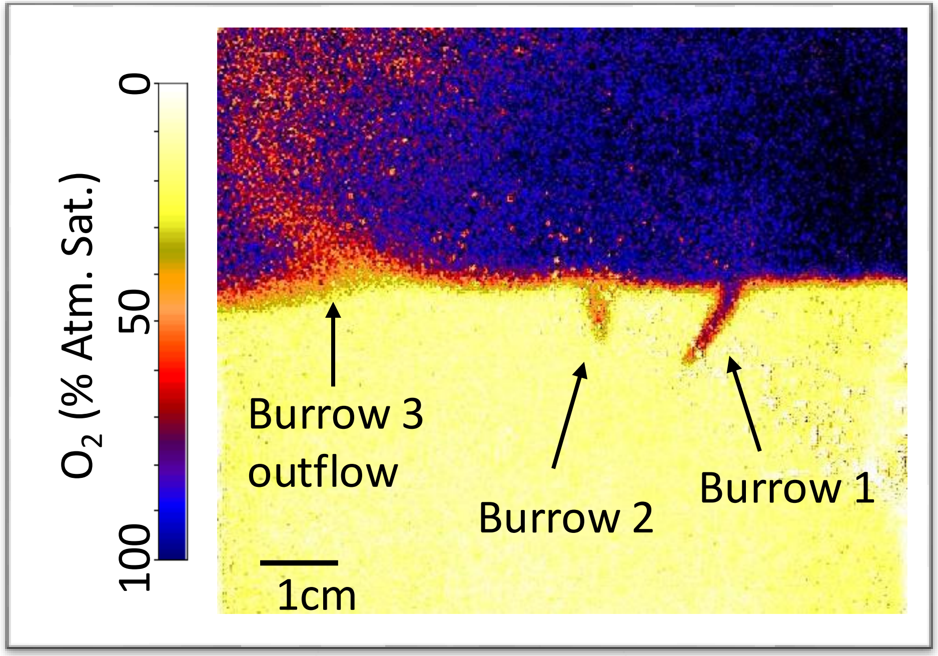
"non-biting midge" "bloodworm"



Imaging study of burrows



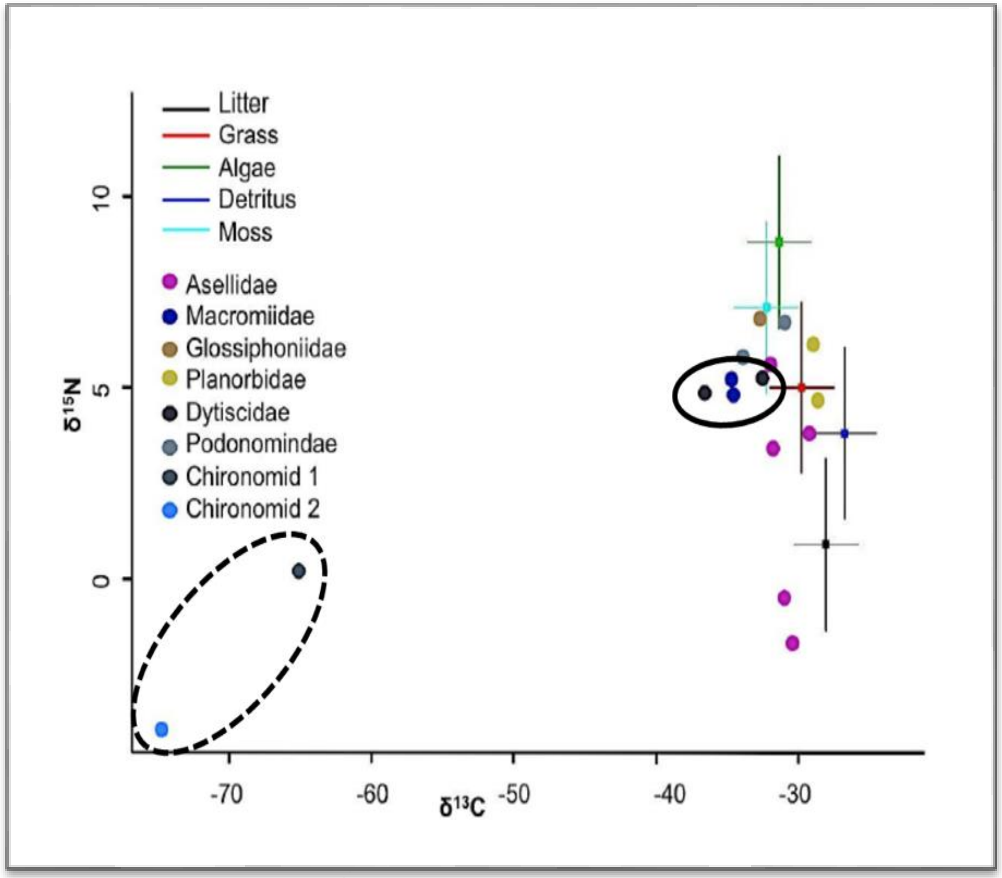
Above-ground 'mound'



Below-ground 'burrows'

Stable isotope analysis of larva

C/N isotope biplot of insects



Chironomids have significantly different isotope signature than other insects indicating diet based on methane-derived carbon

Methane

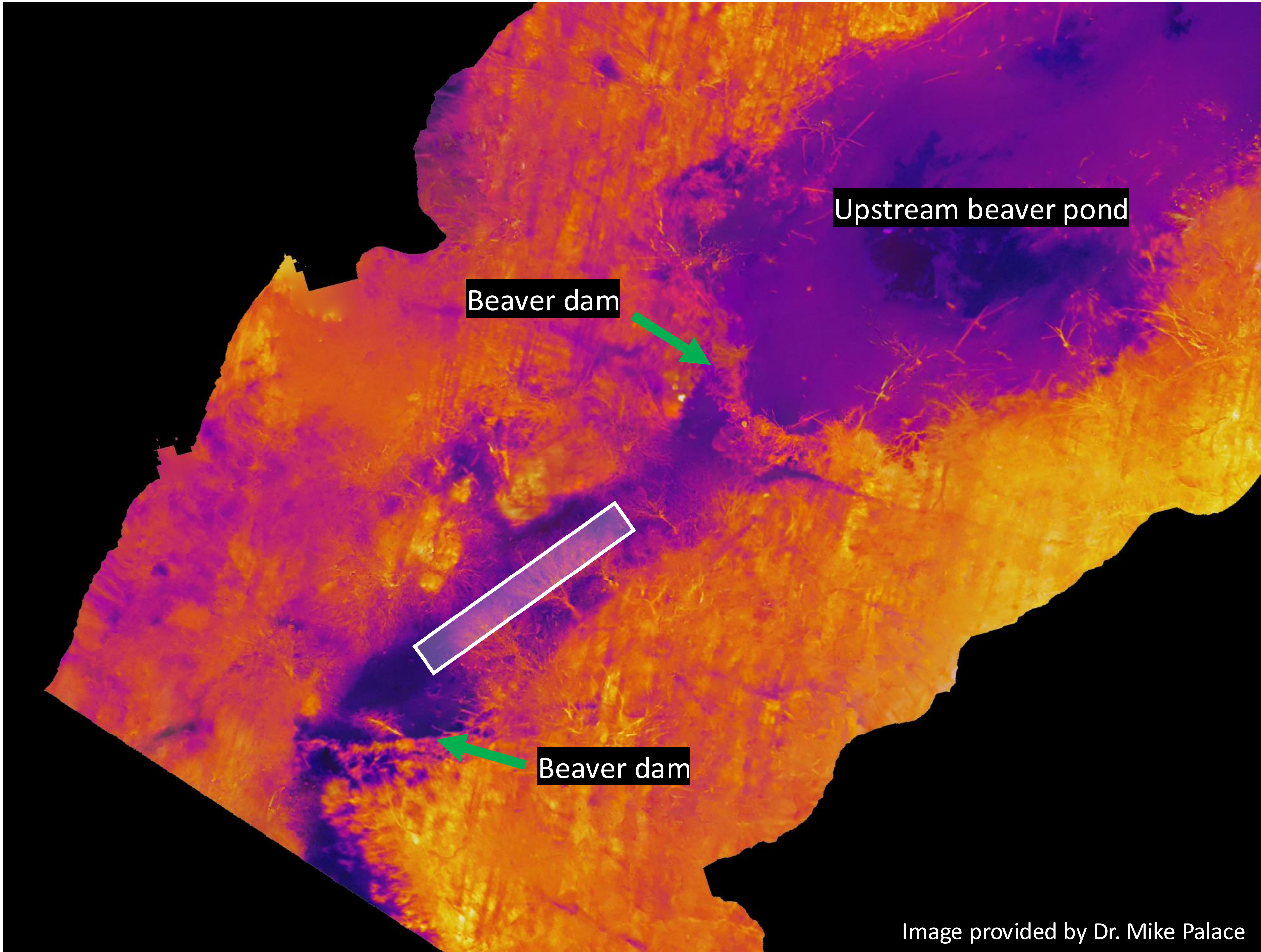
$\delta^{13}C$ (−110 to −50‰)

From Nutrients to Emissions: Dissecting the Eutrophication-Greenhouse Gas Nexus in Beaver Pond Mesocosms

Reese LeVea, PhD student

NRESS, Water Systems Analysis Group, UNH

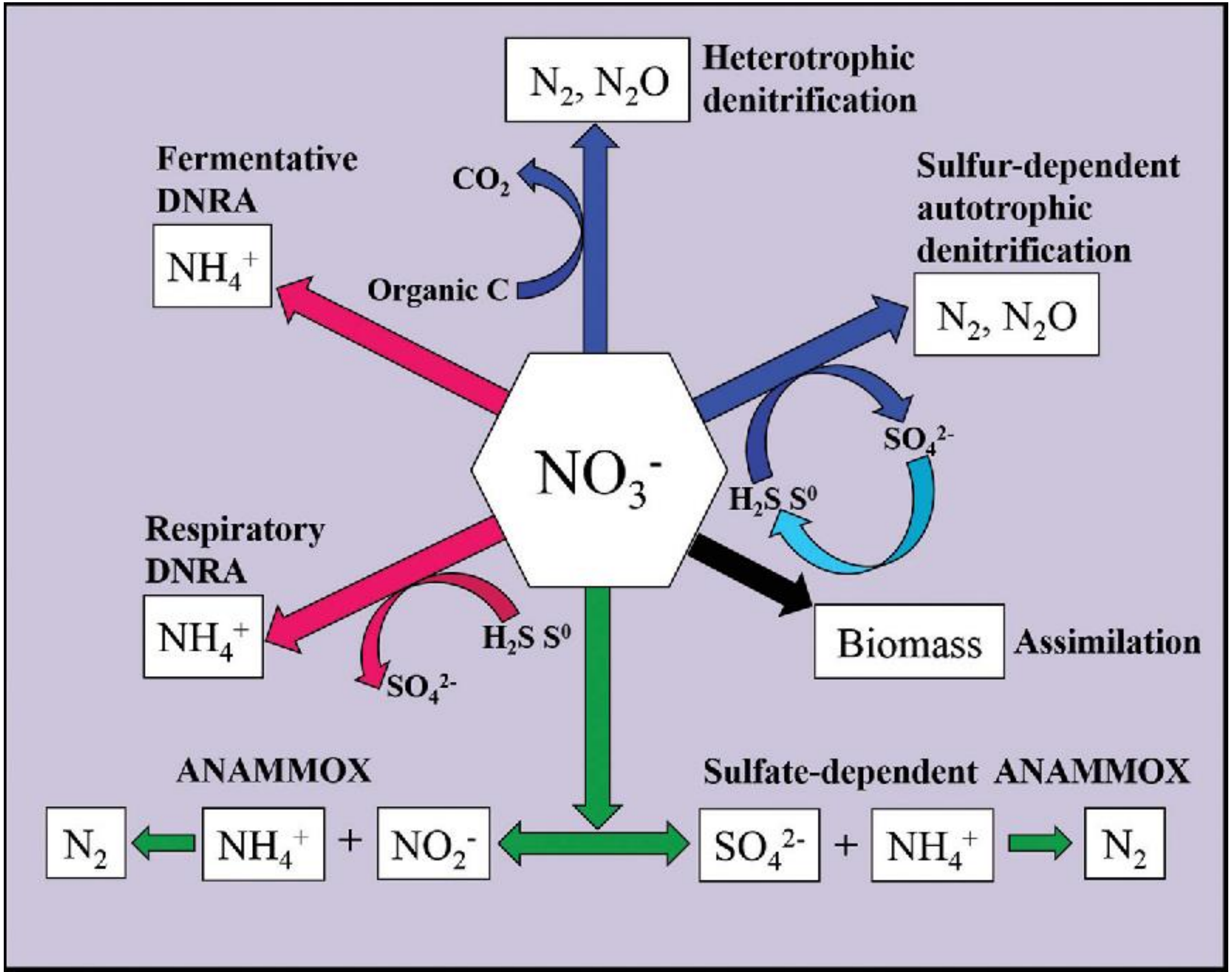
Situated between two beaver dams, mostly controlling water level and flow



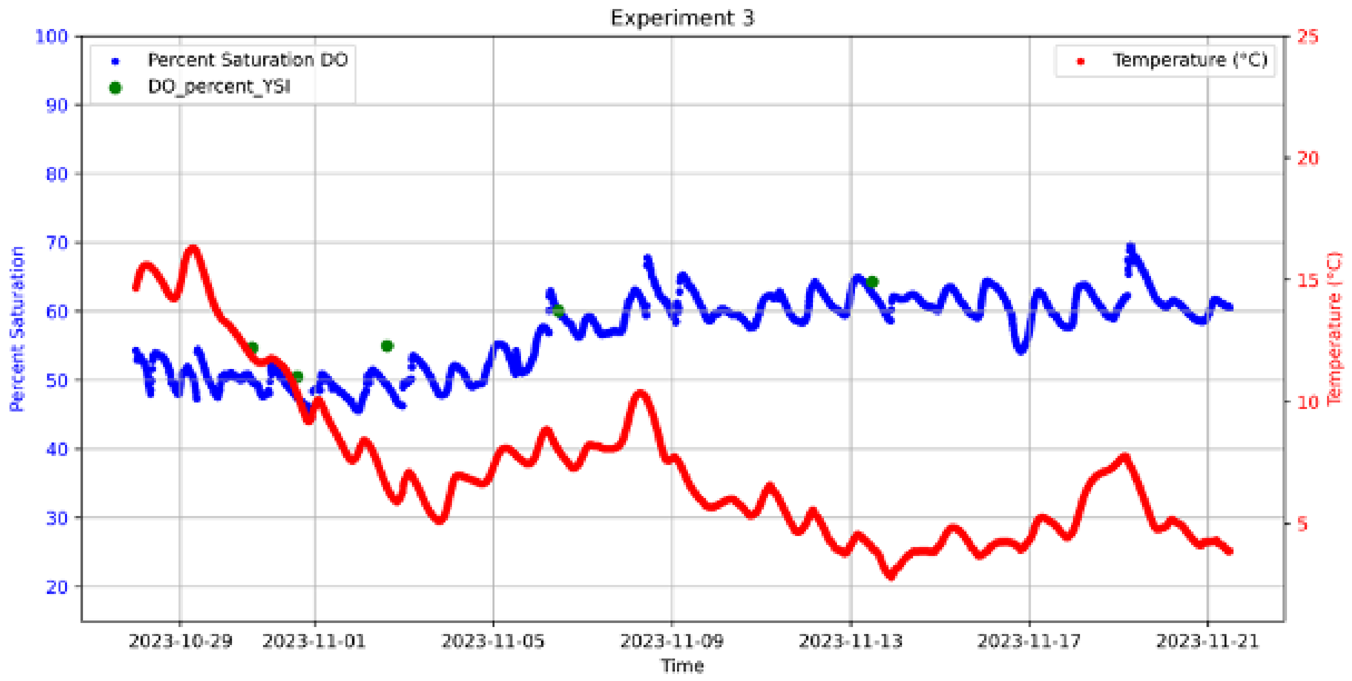
Study setup:

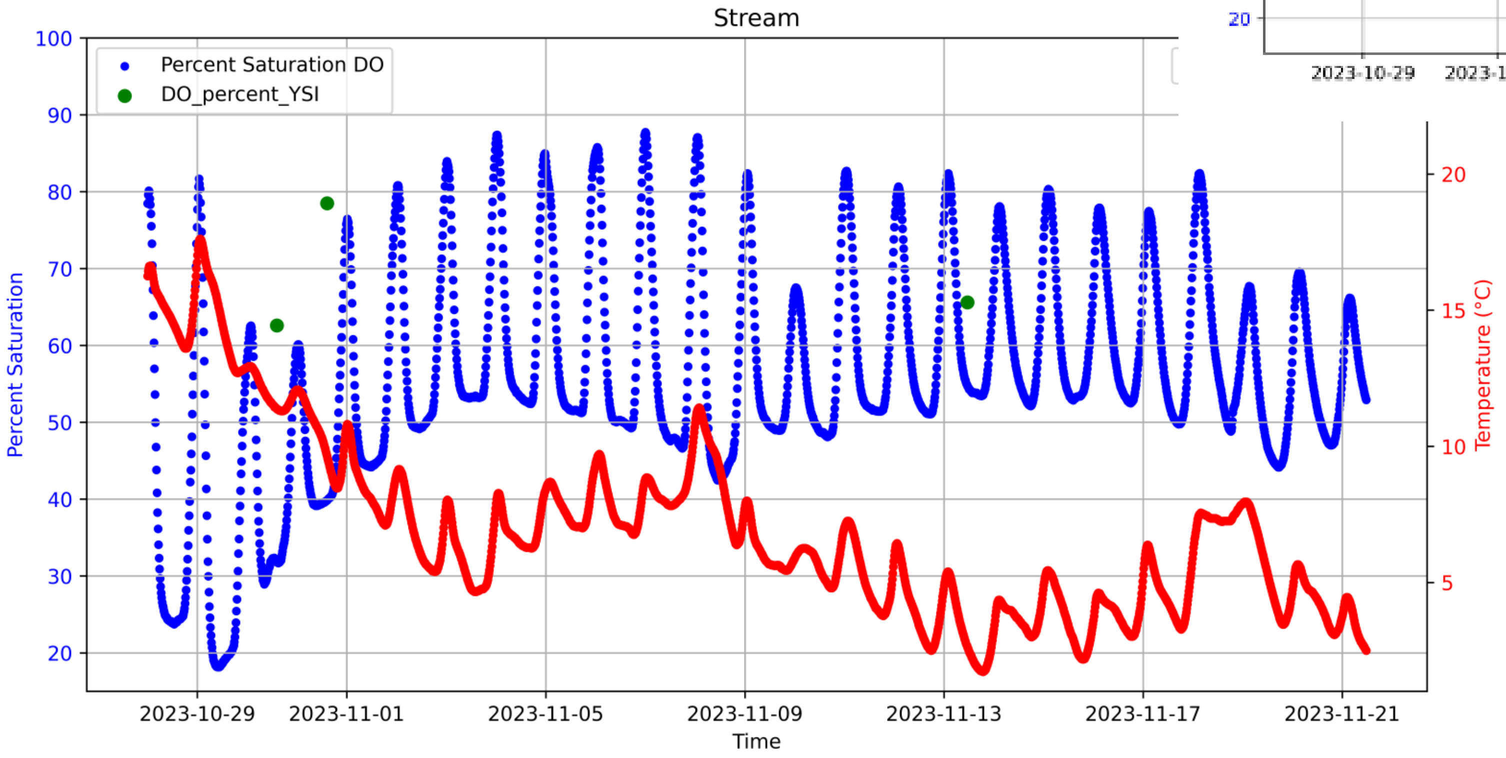
- Mesocosms arranged in a general line, as evenly spaced as possible
- Low vegetation in center of channel, generally homogenous amount in each mesocosm
- Stream site has: DO logger, CH4 ebullition funnel, water level logger, PAR logger
- Conservative tracer: NaCl raised by ~50 mg/L
- NO3 addition: concentration raised by ~2 mg-N/L

3 Main Fates of NO3

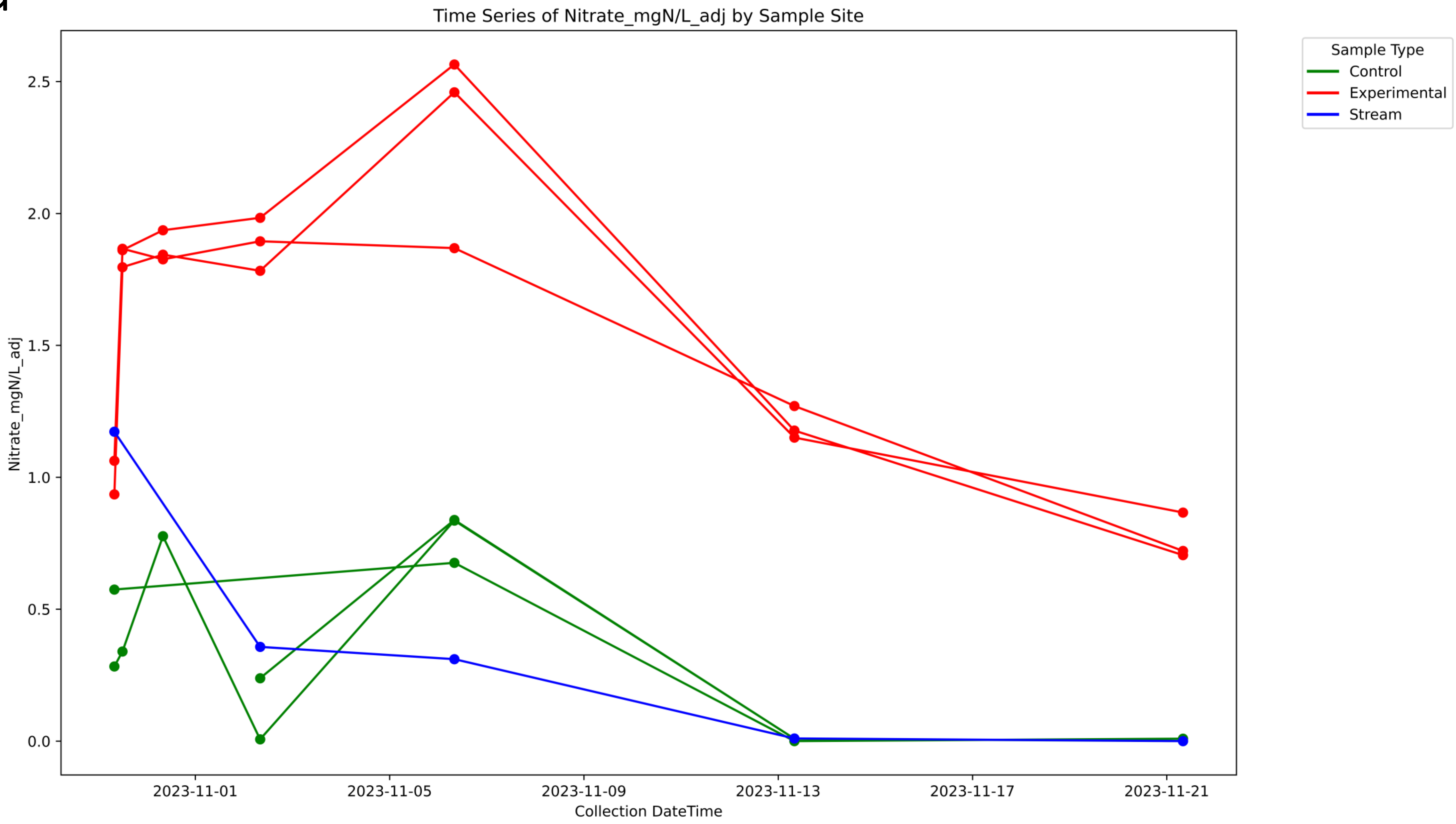


Mesocosms minimized diel variability in DO and Temperature

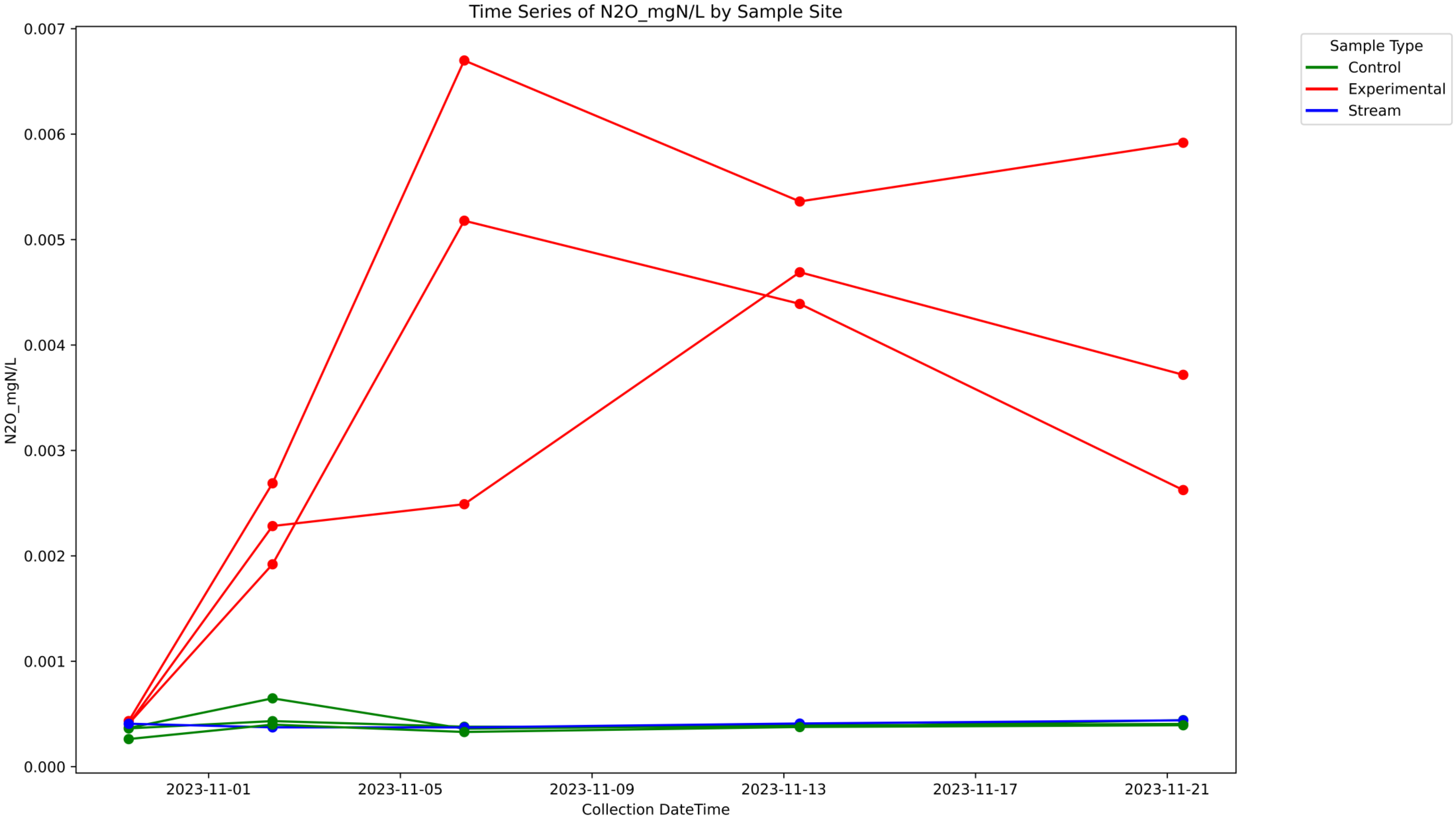




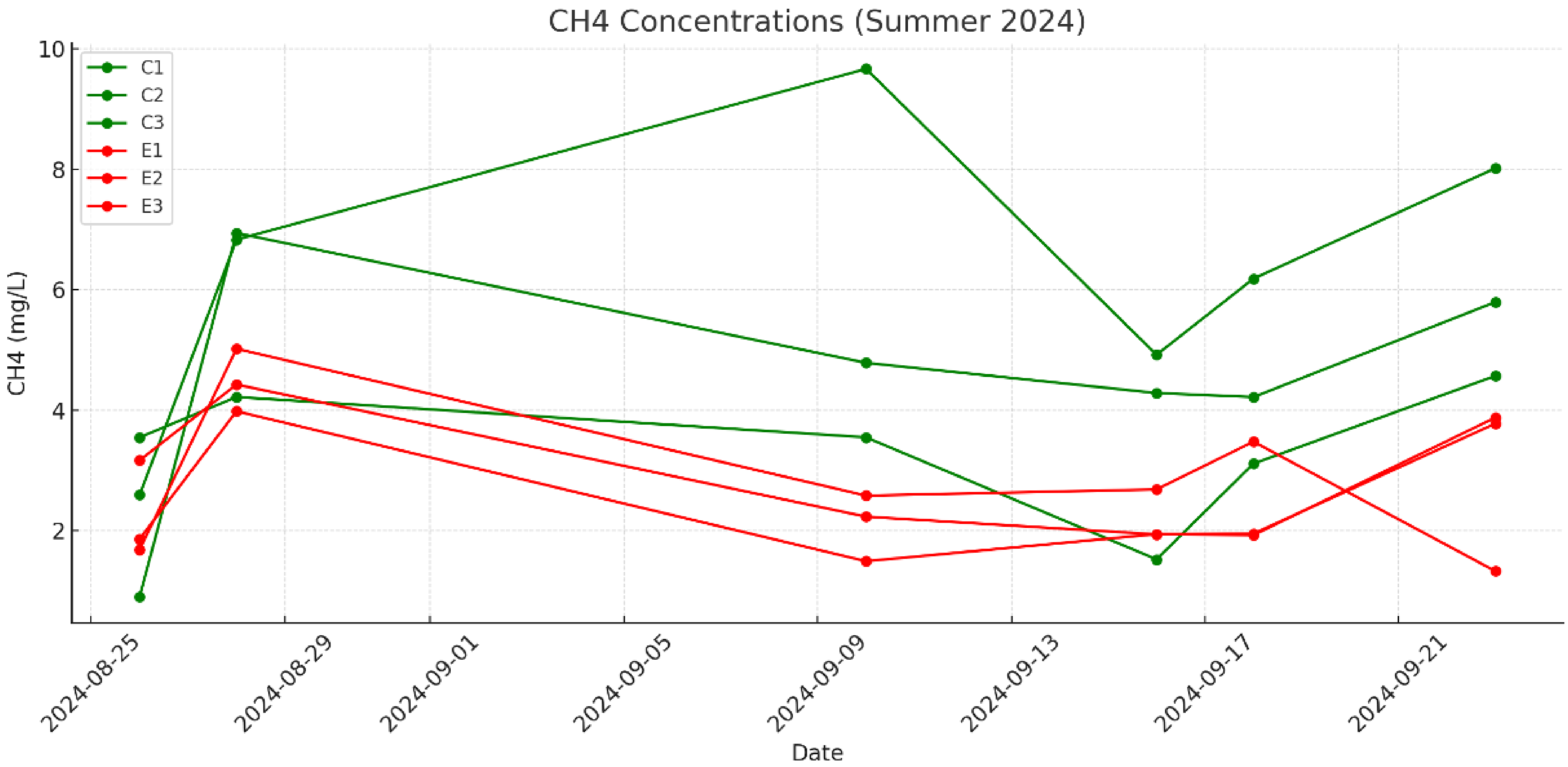
NO3 concentration adjusted for Cl loss – mostly retained



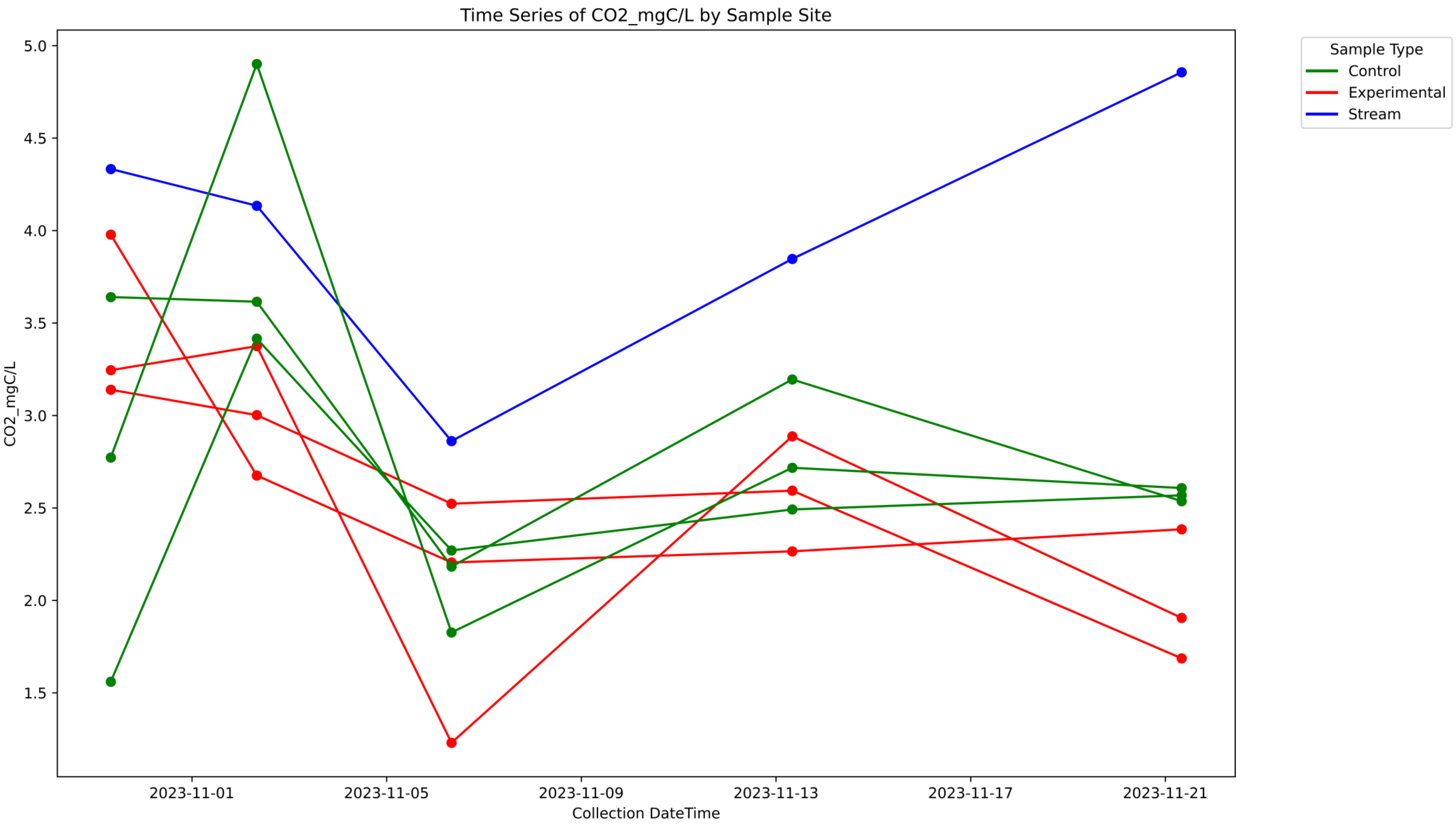
10 to 25x Increase in dissolved N2O Concentration



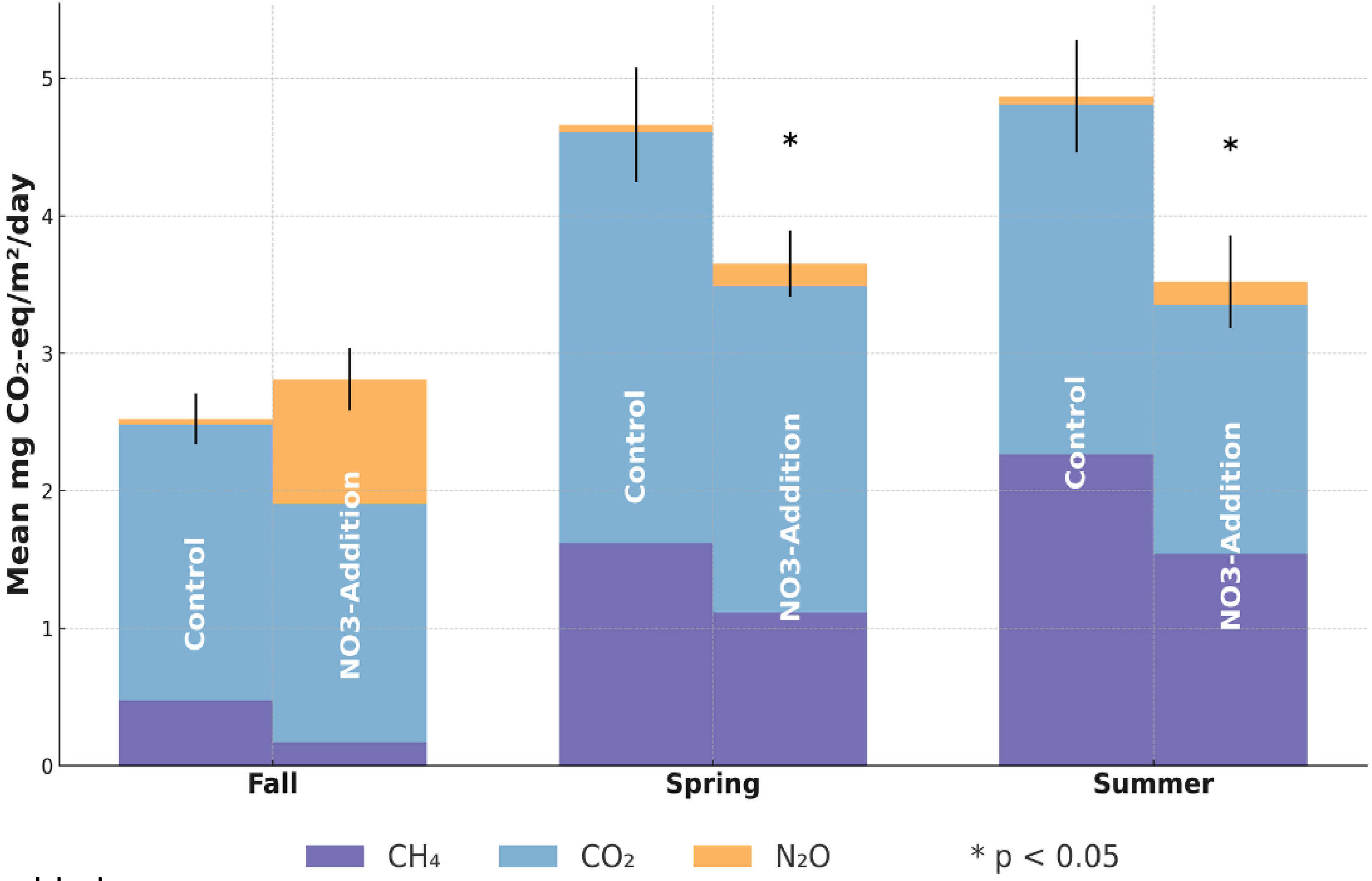
CH4 Concentration Declined in the Experimental Mesocosms



No obvious effect on CO2 Concentration



Greenhouse gas responses as CO2-equivalents

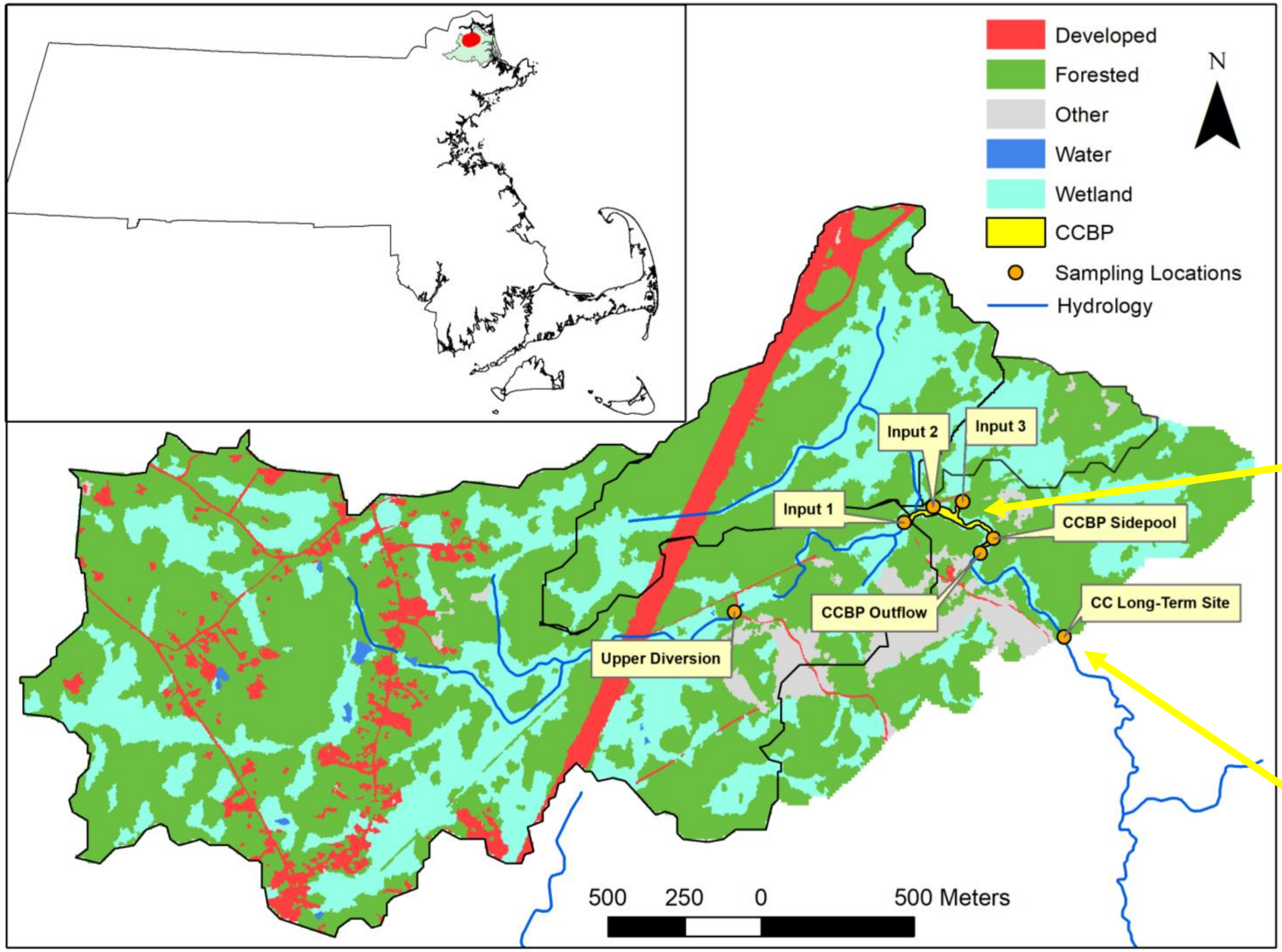


CH4 ebullition to be added

Conclusions

- Beaver Created Ecosystems are dynamic in the landscape, and their function through succession is poorly understand.
  - And very abundant!
- Excellent at removing nitrate, but maybe not total N
  - Source of DON, NH_4
- Denitrification of nitrate removes N permanently, but comes with greater N_2O (a strong greenhouse gas)
- But if nitrate introduced, may lower CH_4 emissions enough so benefit of N removal outweighs cost of greater GHG emissions
- Position of the BCE in river system will affect function
  - High N input from suburban area, or fields?
  - Are other BCE upstream?
- In addition to water storage, sediment storage, habitat including during drought. E Coli sources? Mobilize Mercury?

Study Site



- Cart Creek, Byfield, MA
- 4.6 km^2
- 77% Forested
- 19% Wetland
- PIE LTER long-term site since 2001
- Drains directly to tidal Parker River

Intensively-studied beaver pond

- Long-term chemistry/discharge (since 2001)
- Beaver pond mass balance (since 2015)

PIE LTER long-term sampling location